‘ SIMULTANEOUS AIRBORNE MEASUREMENTS OF CLOUD REFLECTANCE BY A W-BAND RADAR AND MID-INFRARED LIDAR

David M.Tratt and Robert T. Menzies
Laser Remote Sensing Group
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

Gregory A. Sadowy
Dept. of Electrical and Computer Engineering
University of Massachusetts
Amherst, MAO 1003

Fuk K. Li
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

EXTENDED ABSTRACT

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This ~~paper will~~ describe contemporaneous measurements of cloud backscatter by a W-band radar and amid-infrared coherent lidar acquired during a mission aboard the NASA DC-8 research aircraft in summer of 1996. Conclusions gathered from intercomparison will be compared to the results from previous ground-based studies of a similar nature.

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Jet Propulsion Laboratory
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In the summer of 1996 a 94-GHz (3.2 mm) W-band cloud radar (CLOUDRAD[1]) and a 10.6-μm mid-infrared Doppler wind lidar (MACAWS; Multi-center Airborne Coherent Atmospheric Wind Sensor[2]) were deployed aboard the NASA DC-8 research aircraft. Although the primary focus of the lidar is the measurement of wind fields, radiometric calibration of the instrument makes possible the extraction of atmospheric backscatter cross-section profiles as a byproduct. The DC-8 mission overflew several airmasses which exhibited homogeneous, stratiform clouds, thus affording an opportunity to intercompare correlated cloud reflection data acquired by both the CLOUDRAD and MACAWS instruments.

Full characterization of cloud features and their associated radiative properties is vital to improving our understanding of the atmospheric radiation budget, and thus to the study of global climate change issues. A W-band radar with nominal -30 dBZ cloud reflectance sensitivity can detect most radiatively significant cloud types (e.g., cumulus, large particle cirrus) and usually penetrate the entire vertical extent of the cloud mass. However, thin and/or small particle cirrus (most especially so-called subvisual cirrus, which presents the greatest challenge to conventional meteorological observation practises) and thin altocumulus/altostratus remain only marginally detectable at 94 GHz, thus fueling the tendency in recent years to combine radar and lidar methods into a cloud sensor system more comprehensive in scope and capability, In the recent past there have been limited exploratory exercises in combining colocated radar and lidar cloud scattering measurements to infer knowledge of the particle microphysics. The first intensive study of this type was the Cloud Lidar And Radar Exploratory Test (CLARET) conducted in the fall of 1989 and spring of 19913, with subsequent studies being carried out during FIRE 11 the following fall[4]. The former campaign demonstrated that the technique could provide particle size information in good agreement within *situ* measurements of cirrus, with the caveat that discrepancies could be expected due to the non-sphericity of the ice particles. However, and in respect of this, one particularly useful feature of the "hybrid radar/lidar technique is the relative insensitivity of effective particle radius retrieval to measurement imprecision in either the radar or lidar backscatter[3].

The purpose of this paper is to extend the previous body of work by demonstrating that the combined radar/lidar approach to cloud particle sizing is also viable from airborne platforms. Figure 1 illustrates the variation of the ~[3,2-mm]/~[10.6-~m] backscatter ratio for notional separate distributions of ice spherules and water droplets as a function of effective particle radius, r_{eff}:

$$r_{eff} = \frac{\int n(r) r^3 dr}{\int n(r) r^2 dr}$$

in which $n(r)$ represents the size distribution.

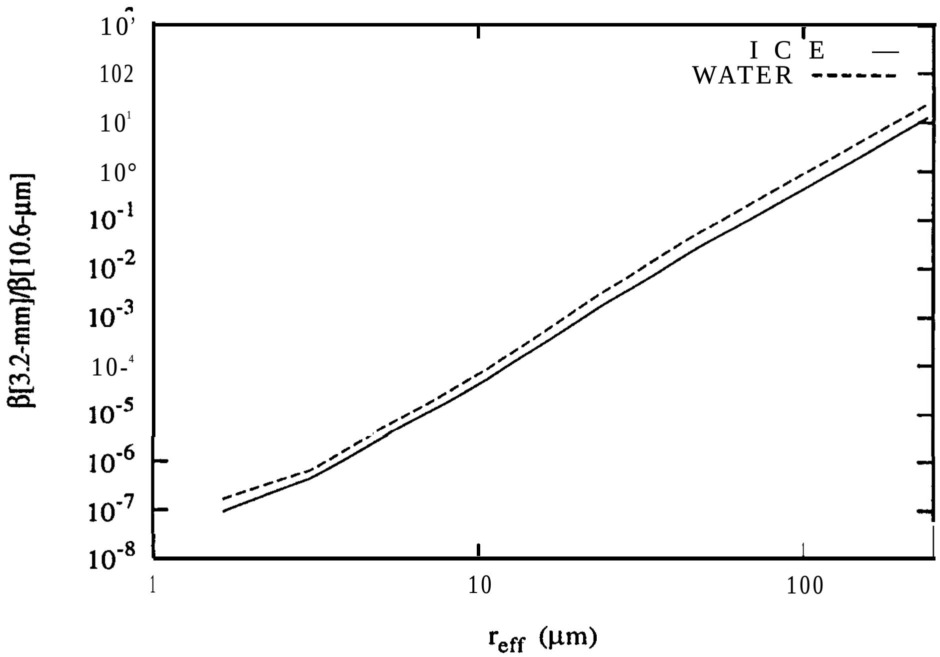

Figure 1. Mie theory projections of 3.2-mm/l 0.6-μm backscatter ratio as a function of particle effective radius for ice and liquid water.

The two relations for ice and water displayed in Figure 1 behave very similarly on a qualitative level, exhibiting a weakly undulating offset factor of -1 .75+ 0.25 throughout the chosen particle size range. This situation is graphically summarized in Figure 2, which shows the dependence of the differential backscatter ratio, B_δ, on r_{eff}, where 'we define B_δ as:

$$B_\delta = \left|\frac{\beta[3.2\text{-}mm]}{\beta[10.6\text{-}\mu m]}\right|_{water} \left|\frac{\beta[3.2\text{-}mm]}{\beta[10.6\text{-}\mu m]}\right|_{ice}$$

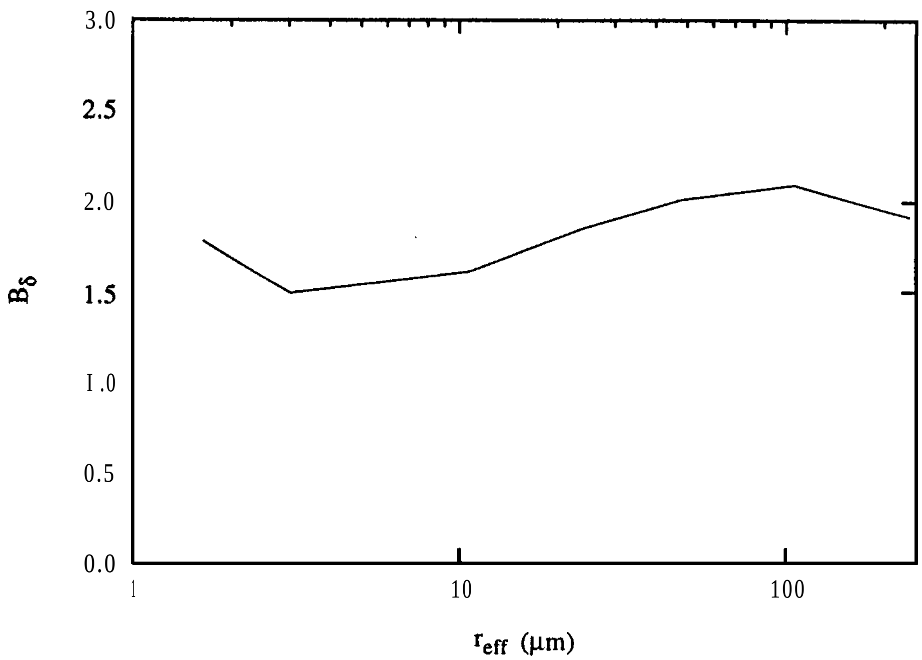

Figure 2. Differential backscatter ratio between the theoretical ice andwater datasets of Figure 1,

CLOUD TYPE	r_{eff} (μm)
Stratus	10
Stratocumulus	10
Cumulus	20
Mid-level cirrus	100-2000
High cirrus	5

Table 1. Typical values of r_{eff} for several common cloud varieties.

Inrelation to Figures 1 and 2, it should be noted that non-precipitating liquid water clouds will typically consist of droplets not exceeding $r_{eff} \sim 20\ \mu$m in size. Table 1 provides typical values of r_{eff} for several of the primary cloud classifications; the radar will be considerably less sensitive to 'particles with $r_{eff} \lesssim 10\ \mu m$ and so will tend to undersample cloud features such as stratus and high, small particle cirrus. It is in these cases especially that the lidar can add most materially to the total picture. Examination of Figures 1 and 2 also suggests that retrieved values of β[3.2-mm]/β[10.6-μm] should permit the identification of mixed-phase clouds.

Acknowledgement

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